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Evaluation of CMAQ Developmental PM_{2.5} Prediction over Southern Ontario, Canada

With Measurements and GEM-MACH15 and UMOS-AQ Predictions

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Acknowledgements

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Preliminary measurement data were provided by
Ontario Ministry of the Environment



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Presentation Overview

- Area of Verification
- Data Collection
- Model Comparison
- Components of Evaluation
- Preliminary Results
- Evaluation Summary

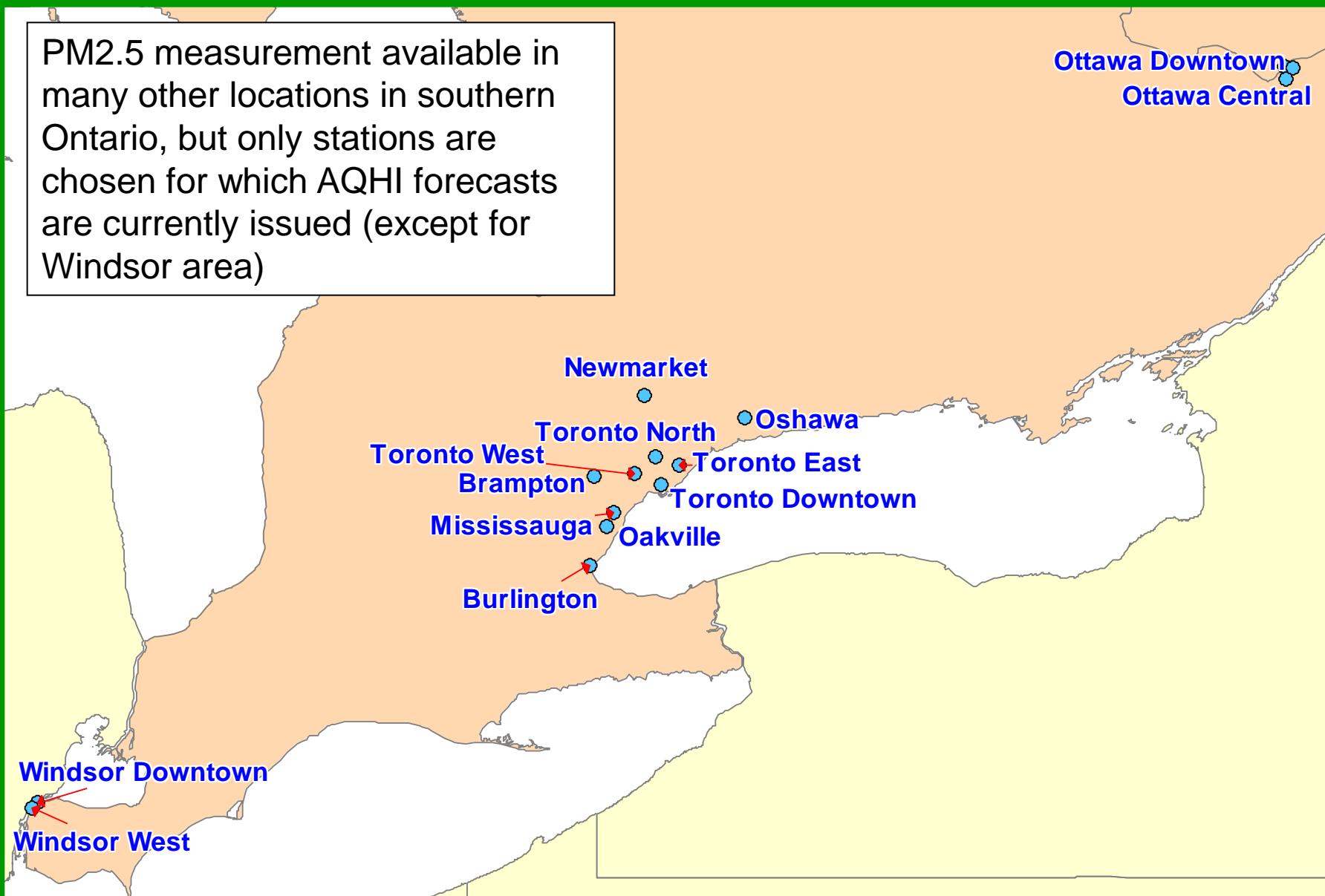


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Area of Verification

PM2.5 measurement available in many other locations in southern Ontario, but only stations are chosen for which AQHI forecasts are currently issued (except for Windsor area)



Data Collection

- Evaluation Period: August 1st 2009 – July 31st 2010;
- Hourly measurement data obtained from the Ontario Ministry of the Environment;
- 12Z hourly GEM-MACH15 gridded outputs bi-linearly interpolated to 14 surface sites in Ontario;
- 12Z hourly CMAQ PM_{2.5} developmental products for CONUS domain in grib1 format bi-linearly interpolated to 14 surface sites;
- 12Z hourly UMOS-AQ experimental products. UMOS-AQ is a post-processing tool that uses GEM-MACH15 outputs as predictors and applies MLR to modify NWP model predictions.



Model Comparison

- **GEM-MACH15 v1.3.0a**

- Meteorology: GEM v.3.3.0, Physics 4.5 Regional 15km
- Chemistry:
 - ADOM-II gas-phase chemistry, ADOM aqueous-phase chemistry
 - HETV heterogeneous chemistry, IAY SOA scheme
 - 2-bin sectional representation of PM size distribution with 9 chemical components
- Emissions:
 - Year 2006 Canada and 2005 US inventories
 - Emissions split into 12 monthly file sets, each with daily and hourly variations
 - Improved biogenic emissions
 - Improved land-use database
 - Improved emission factors

Sources: Anselmo et al, 2010 and Moran et al, 2009

- **CMAQ**

- Meteorology: WRF-NMM configured to cover NA -12 km
- Chemistry:
 - AERO4 module with corresponding gaseous mechanism CB05
 - Cloud processed & aqueous-phase chemistry
 - 3 modes (Aitken, accumulation, coarse) with 12 species to contribute to PM composition
- Emissions:
 - Year 2005 US, 2000 Canada and 1999 Mexico inventories
 - Emissions split based on the time-activity pattern, and diurnal variability of different vehicle types
 - OTAQ 2005 on-road emission inventory
 - Updated Biogenic Emission Inventory System

Sources courtesy of Youhua Tang and <http://www.emc.ncep.noaa.gov/mmb/aq/>

Components of Evaluation

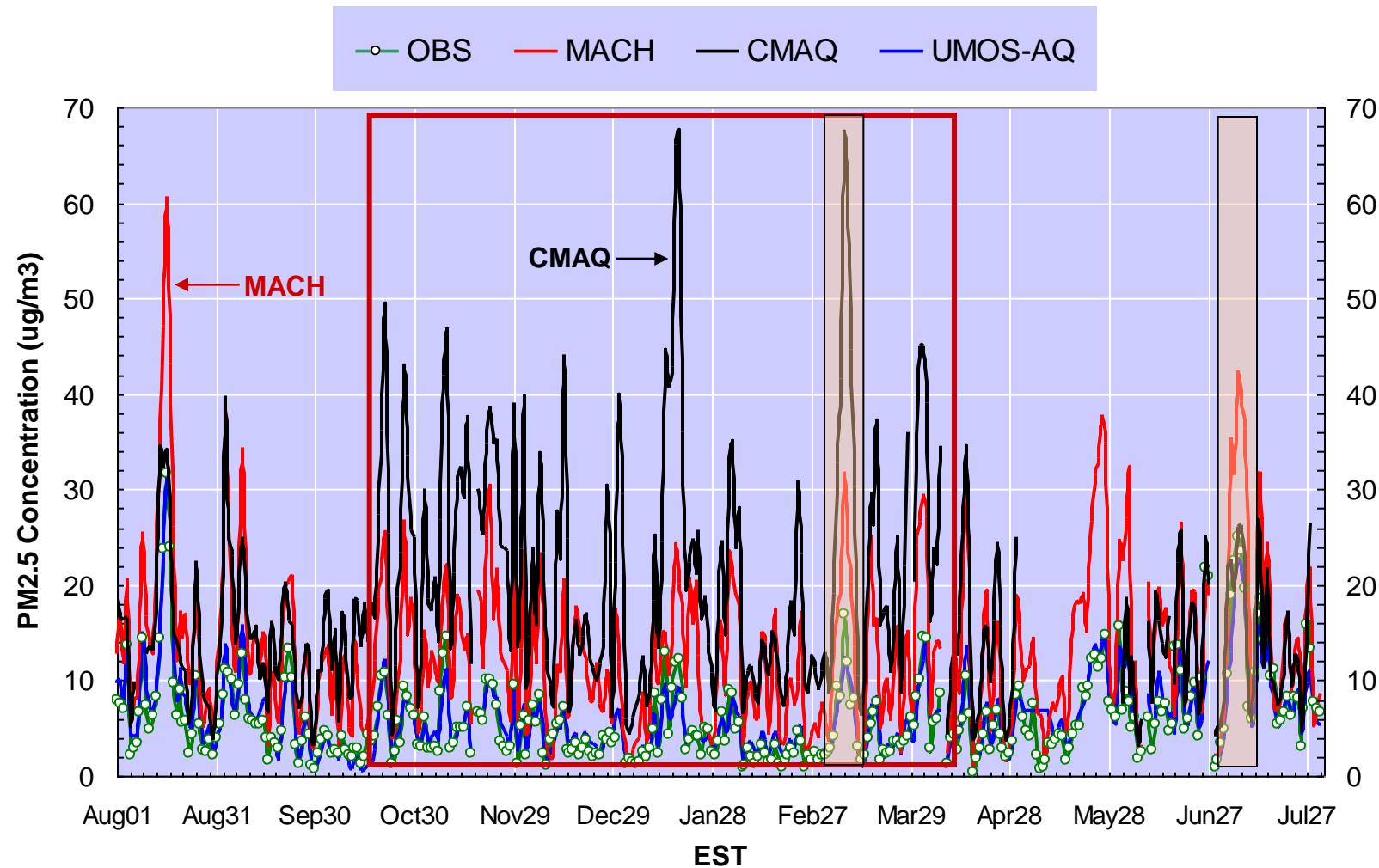
- Seasonal variation and distribution
- Diurnal evolution
- Statistical metrics
- Case Studies



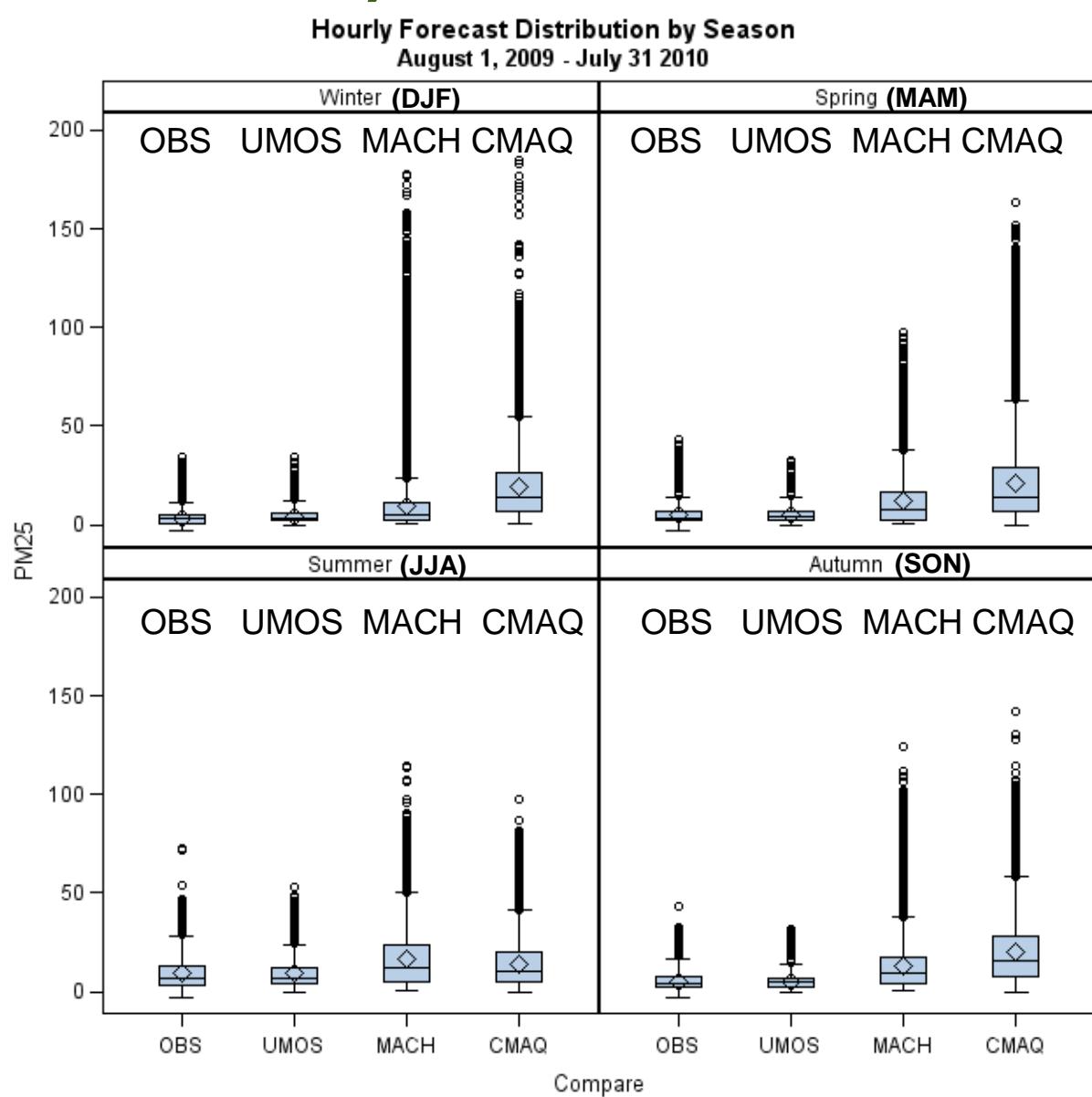
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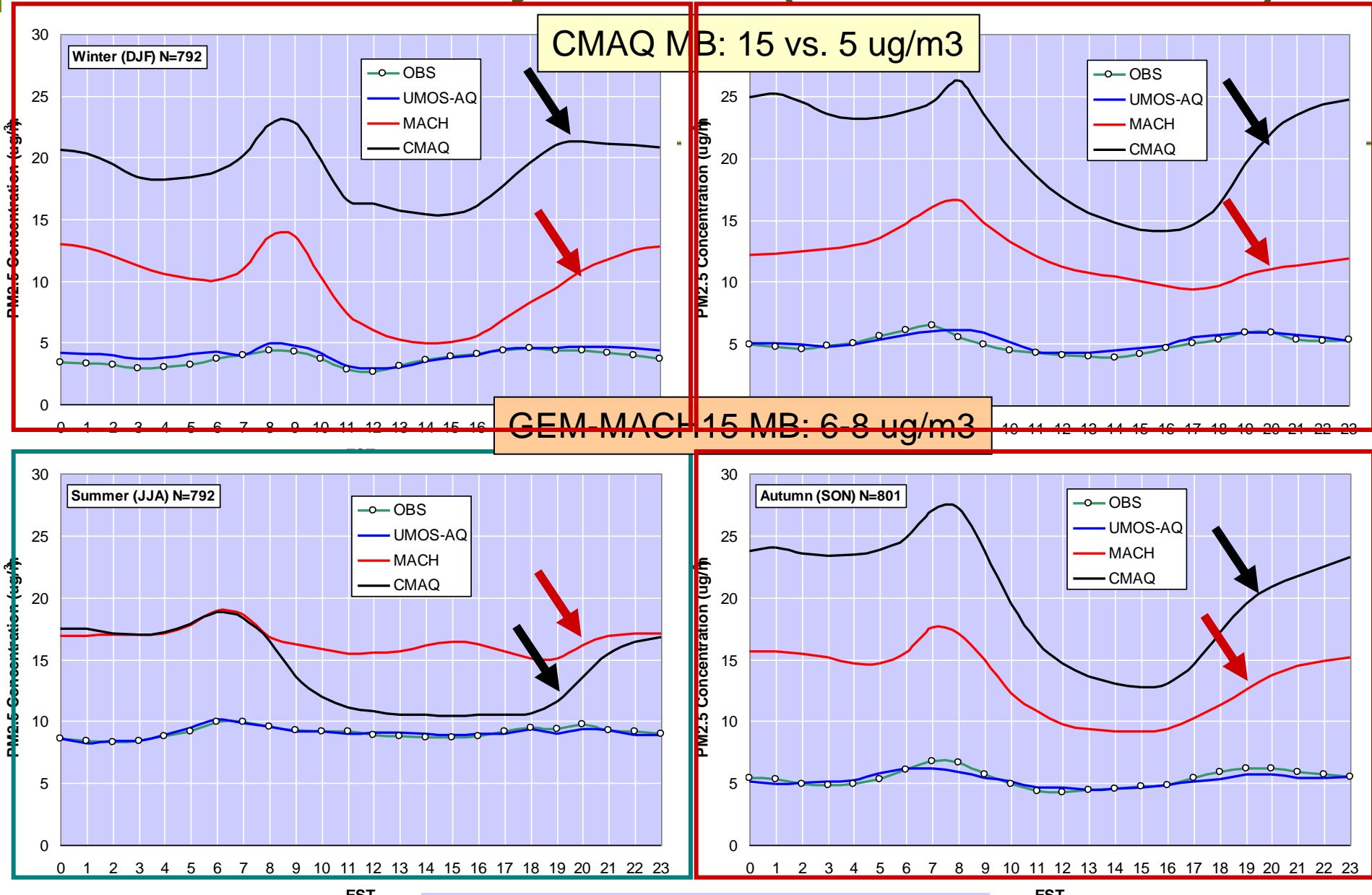
24-hour Mean PM_{2.5} Concentration (Areal averaged over 14 sites in Ontario)



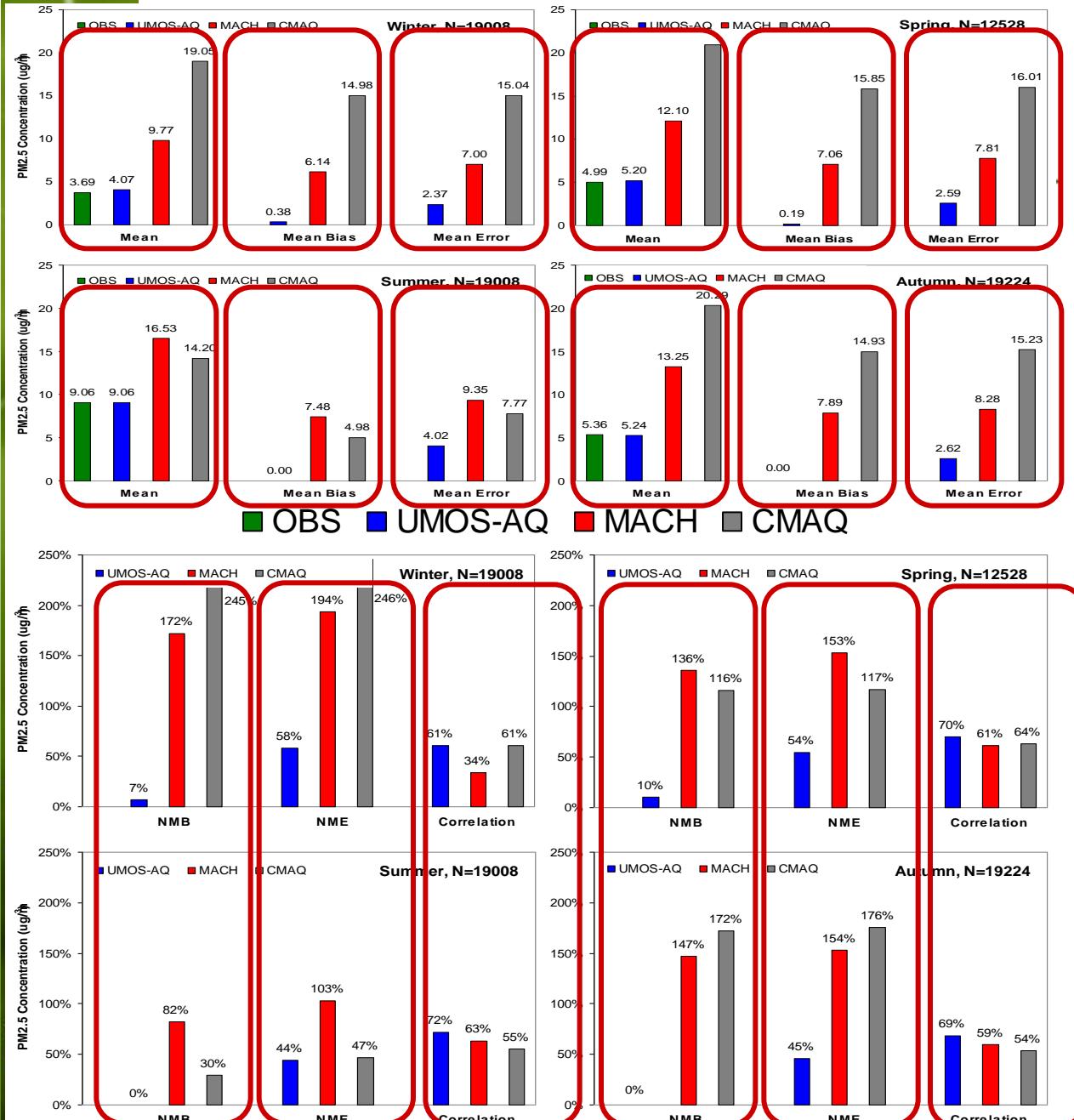
Hourly Distribution by Season (all sites combined)



Diurnal Evolution by Season (all sites combined)



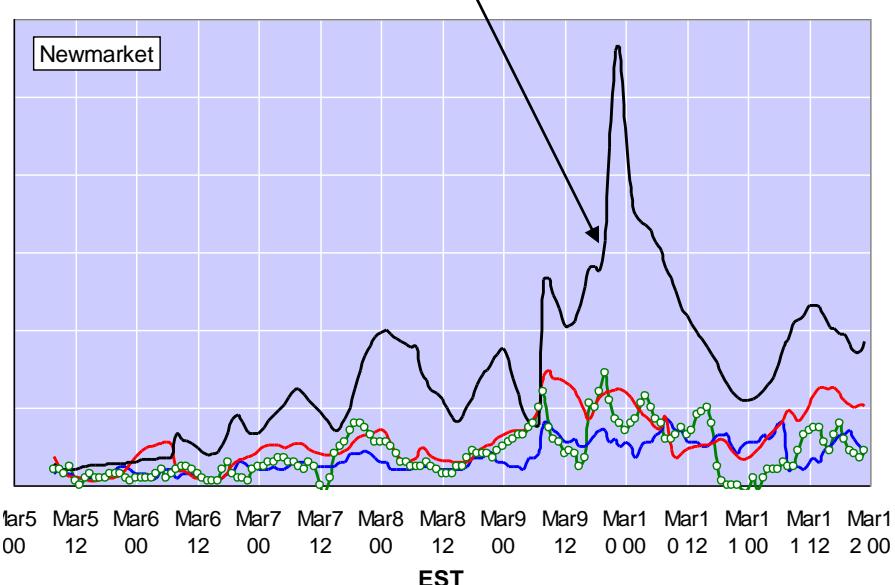
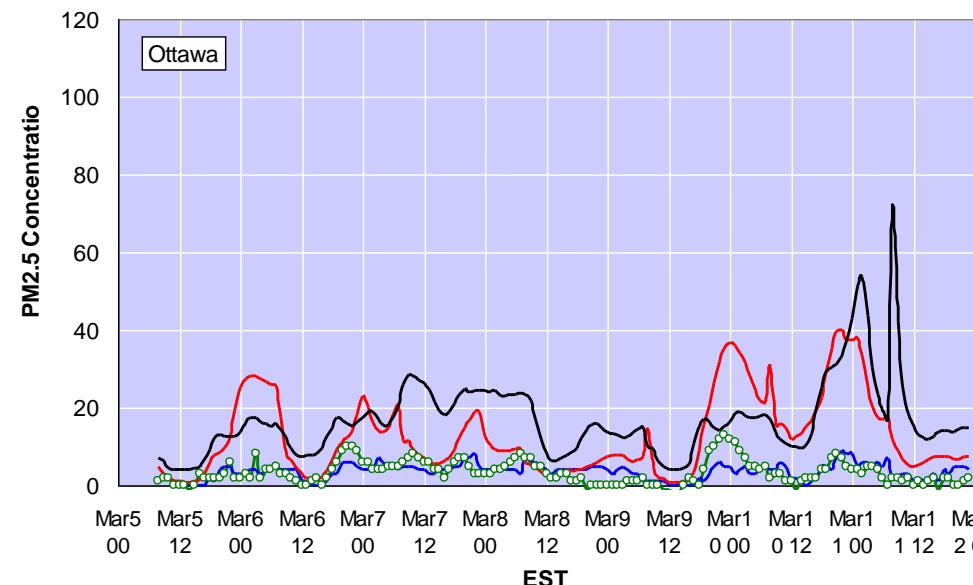
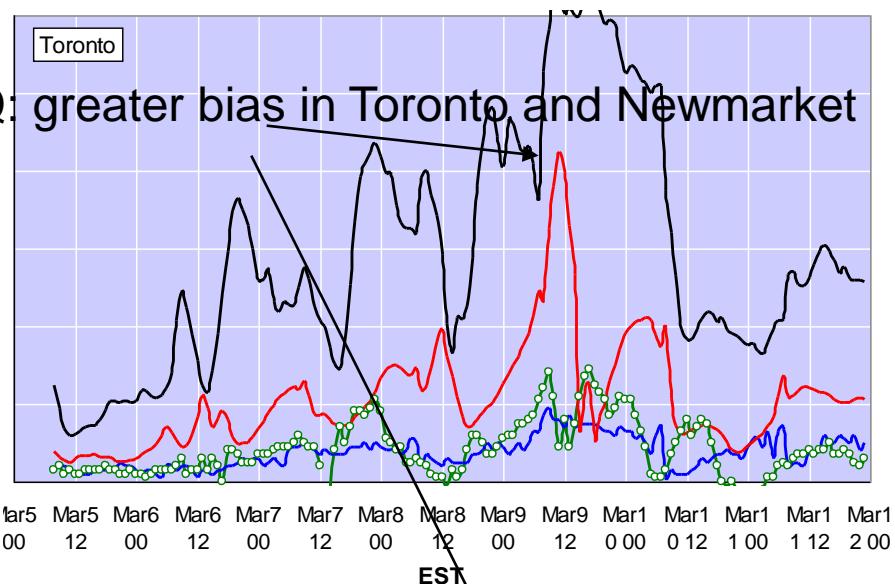
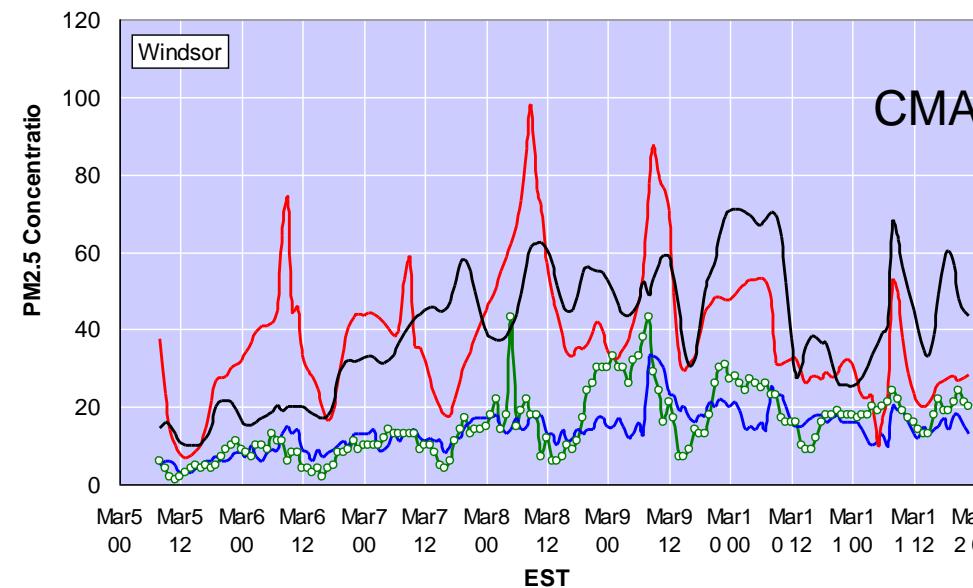
Seasonal Error Statistics



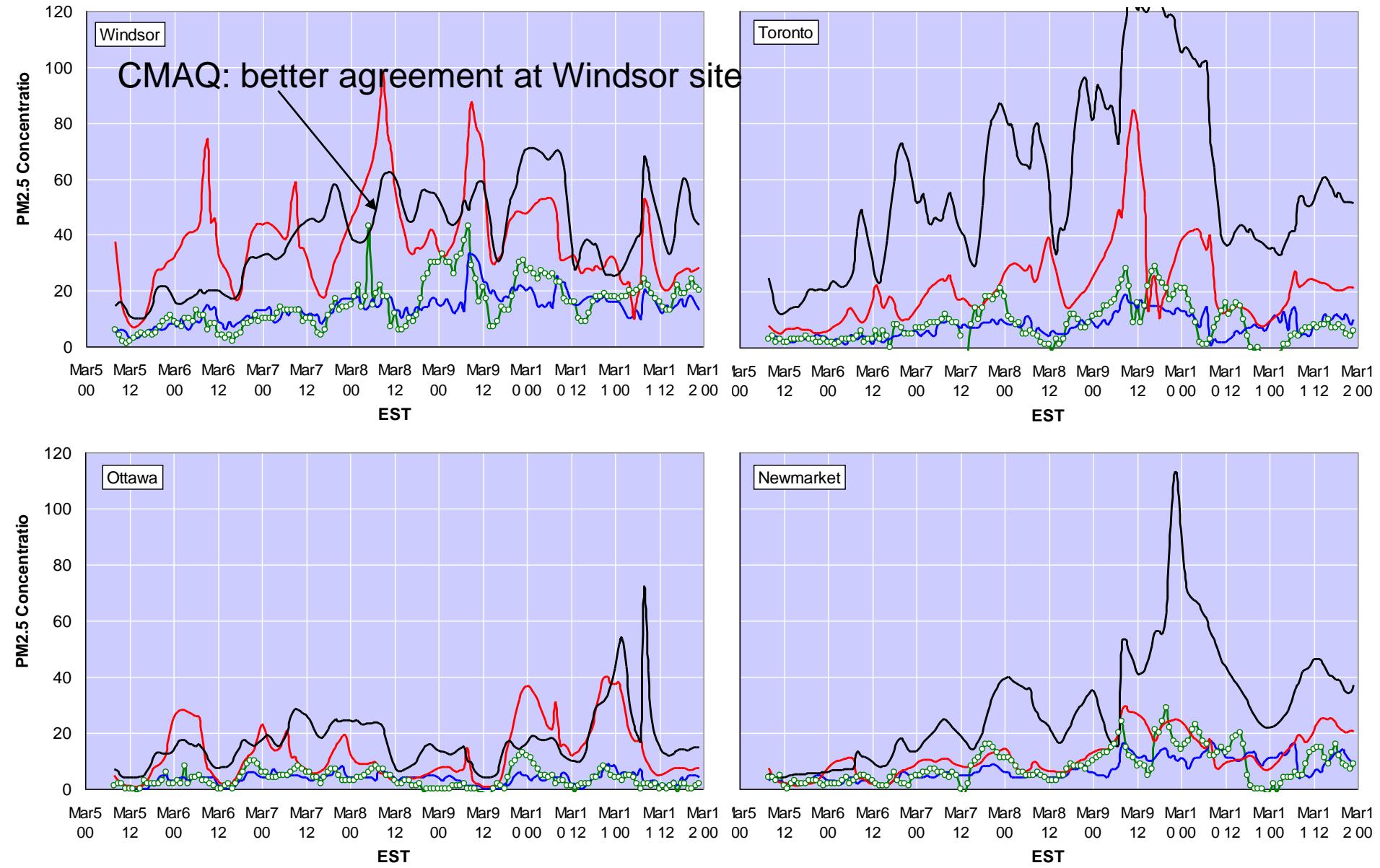
For the specific study period and the urban centres in Ontario:

- Both numerical models tend to over-predict daily mean PM_{2.5} year-round
- During cold season, GEM-MACH15 had a lower bias and error than CMAQ.
- During warm season, particularly in the summer months, CMAQ modeled daily mean PM_{2.5} is in better agreement with measurements
- UMOS-AQ remarkably improved GEM-MACH15 predictions.

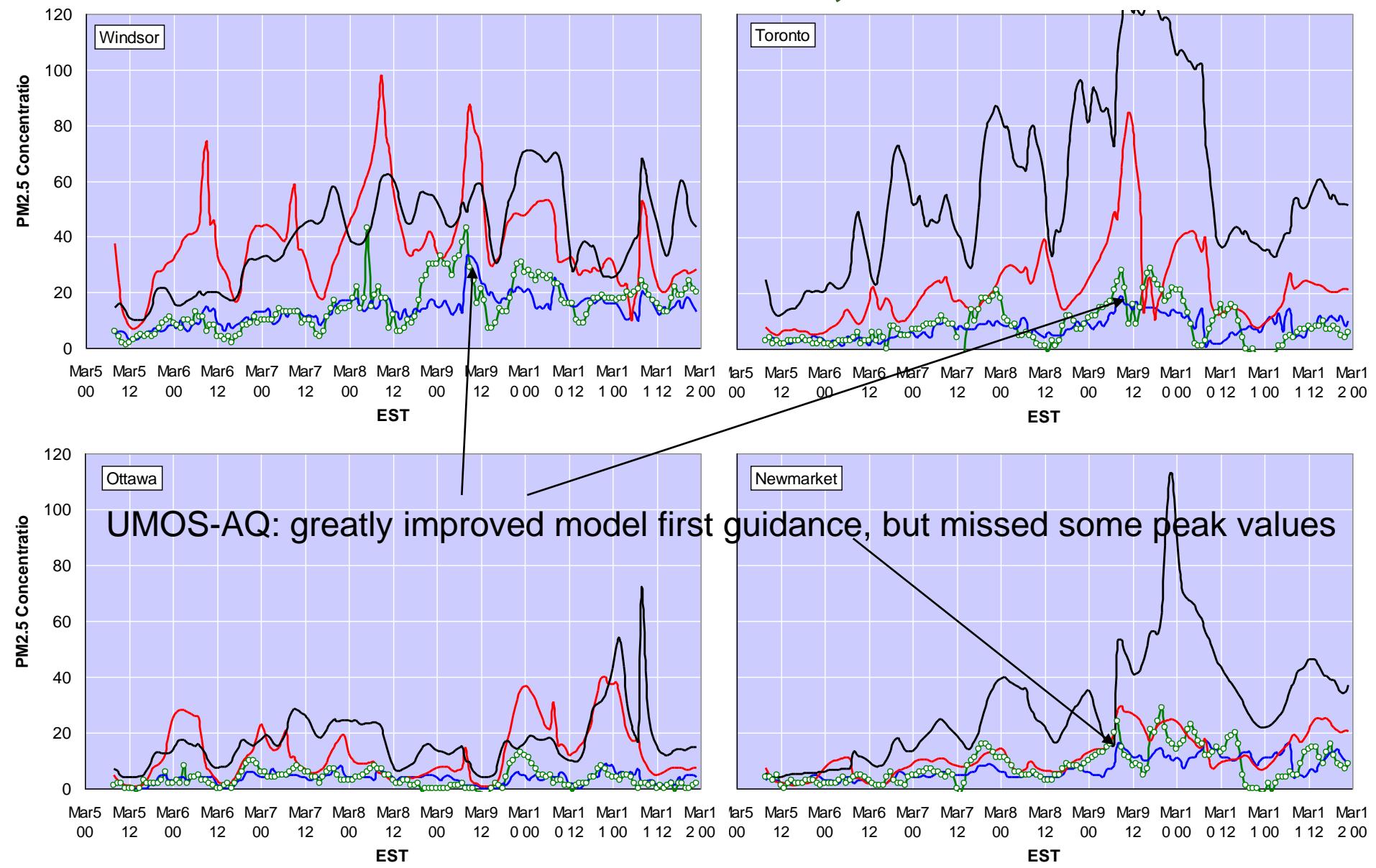
Case Study#1: March 5-11, 2010



Case Study#1: March 5-11, 2010



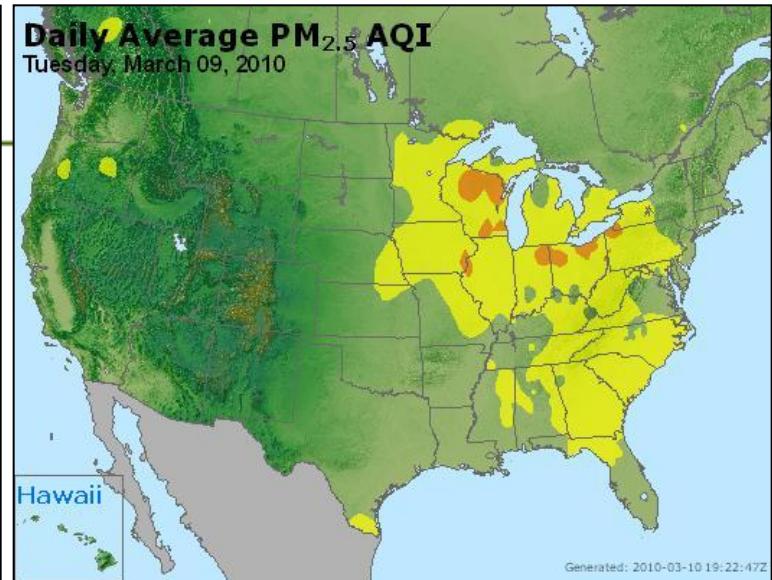
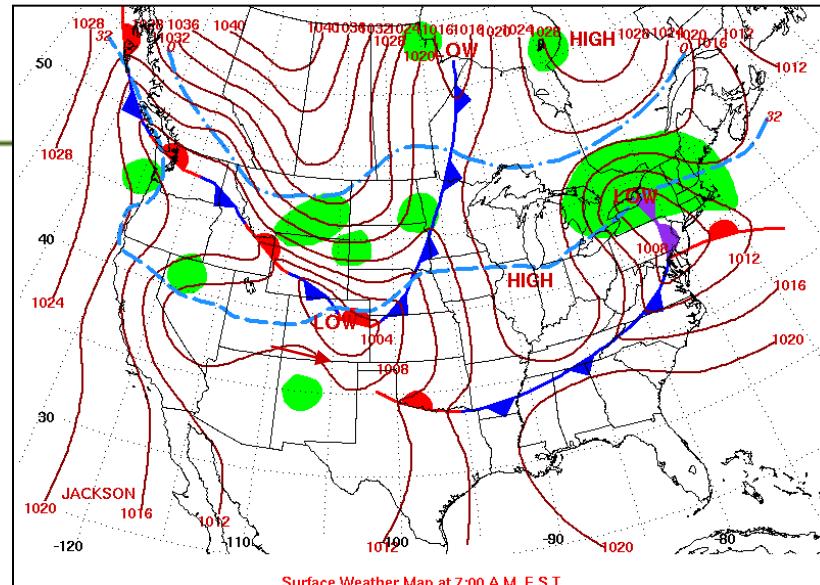
Case Study#1: March 5-11, 2010



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Case Study #1: Focus on March 9, 2010



Synoptic situation contributing to poor air quality:

- A ridge of high pressure situated over the Great Lakes/Ohio River Valley for the past few days
- Stagnant conditions allowed pollutants to accumulate.

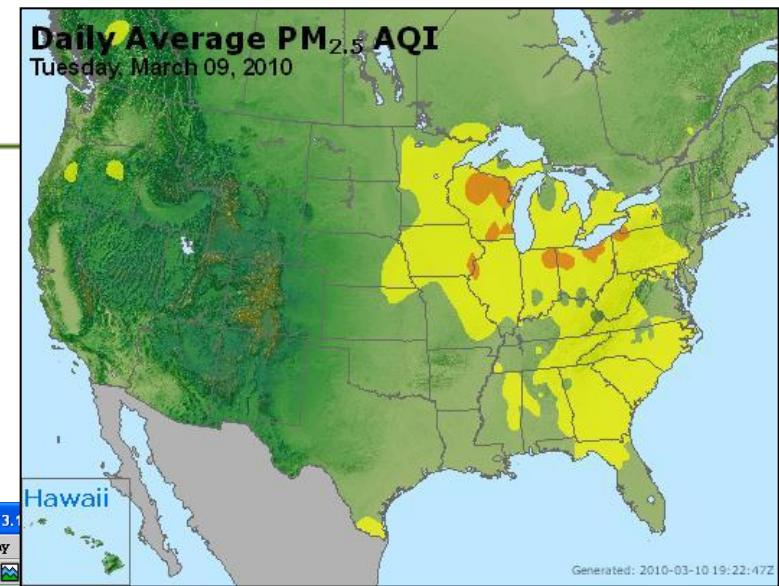
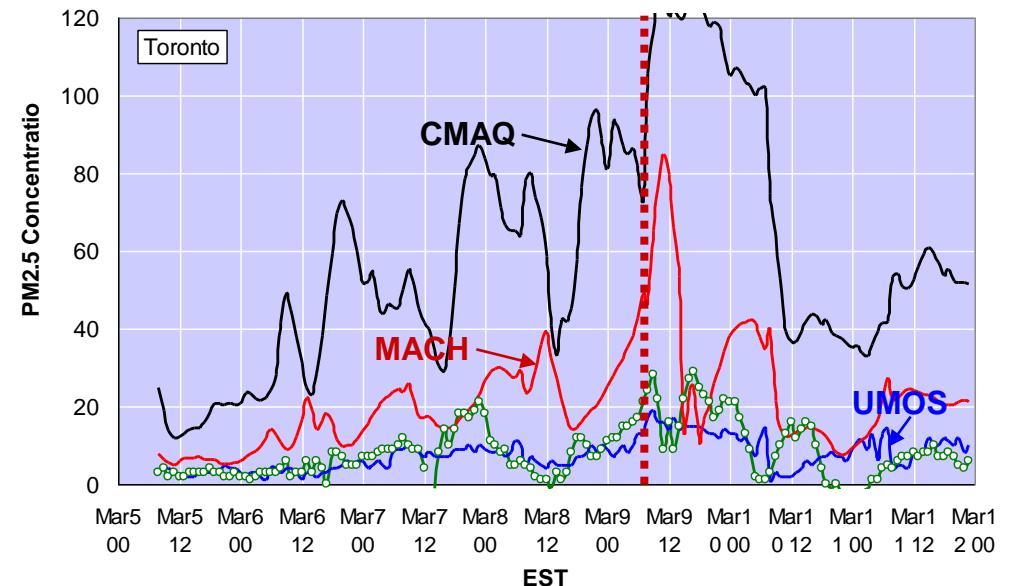
Moderate to high risk hourly AQHI (6-7) at most of the forecast sites in Southern Ontario



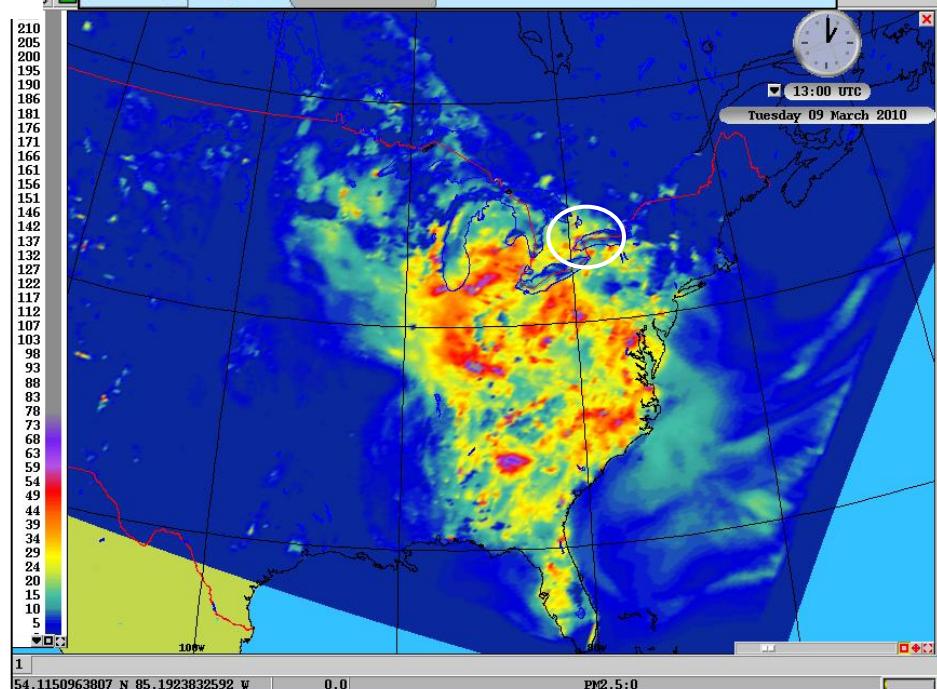
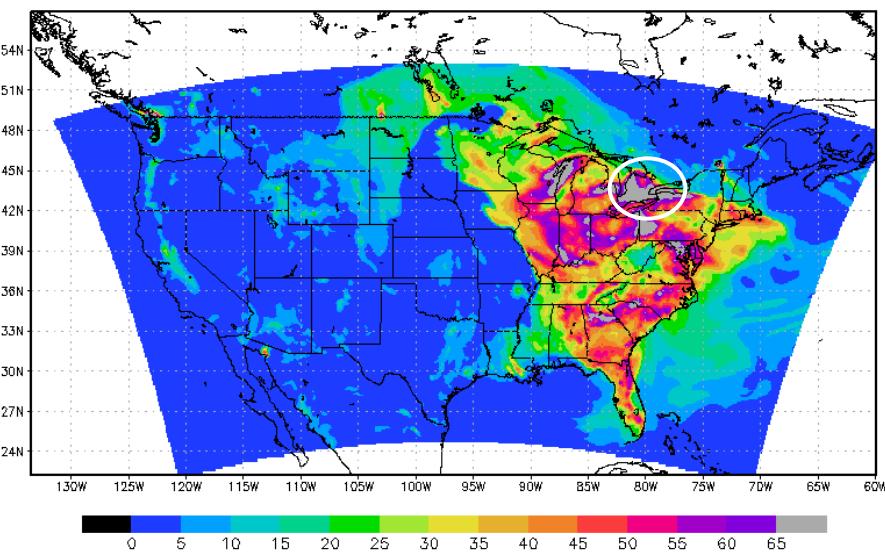
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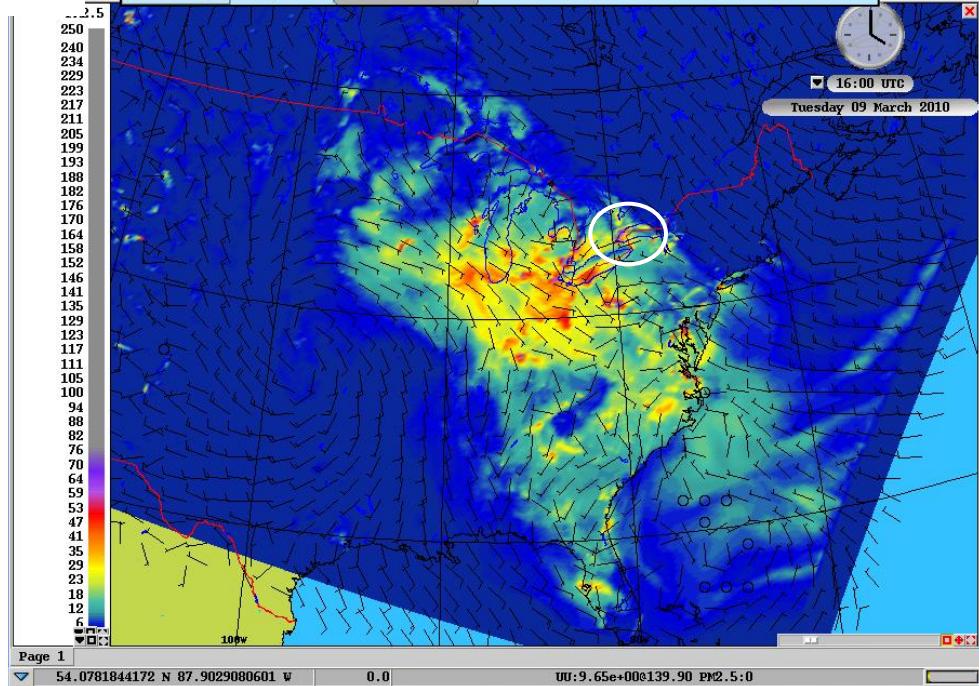
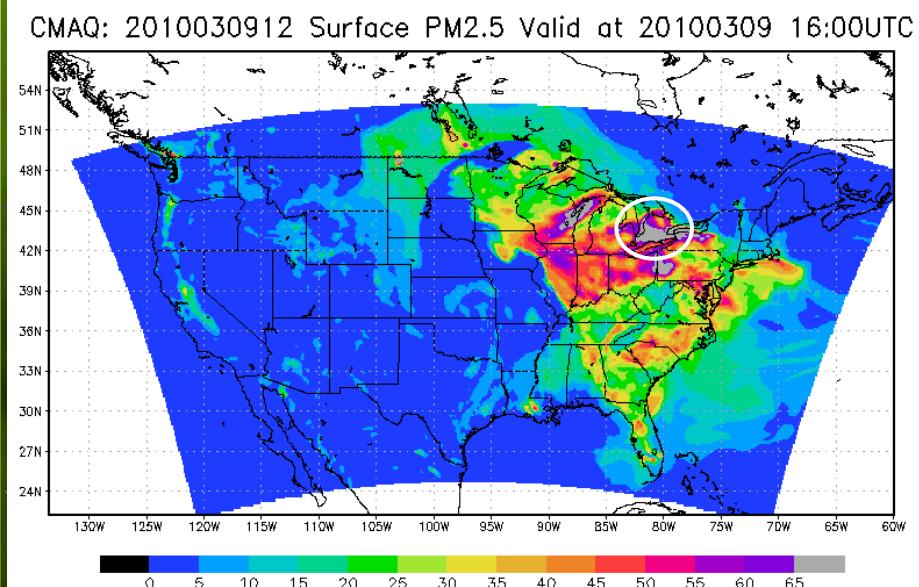
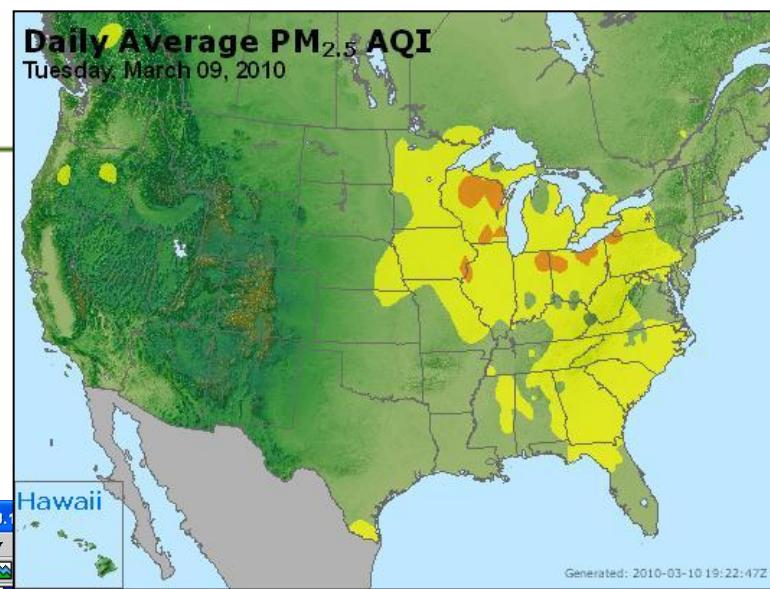
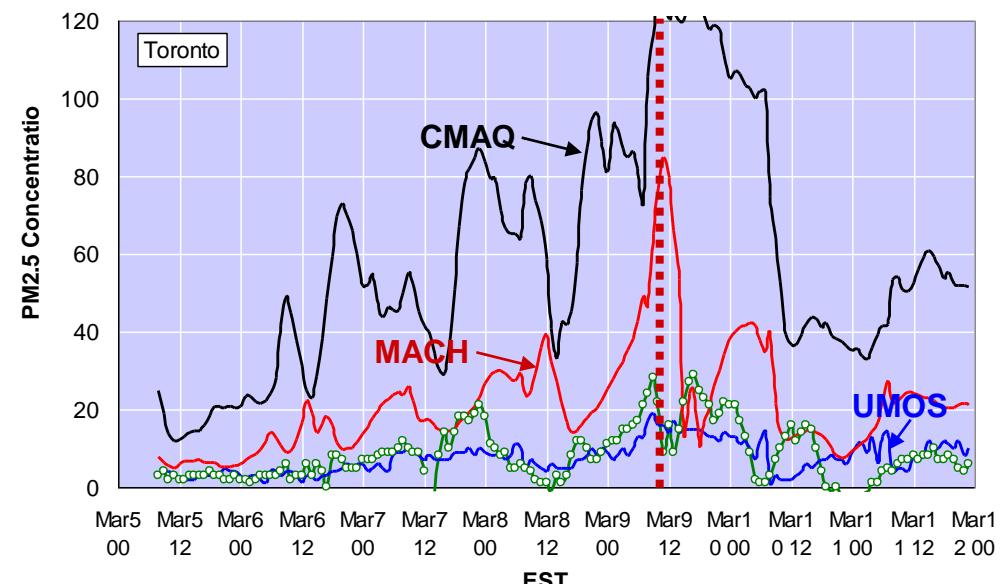
Case Study#1: March 09, 2010, 1300 UTC



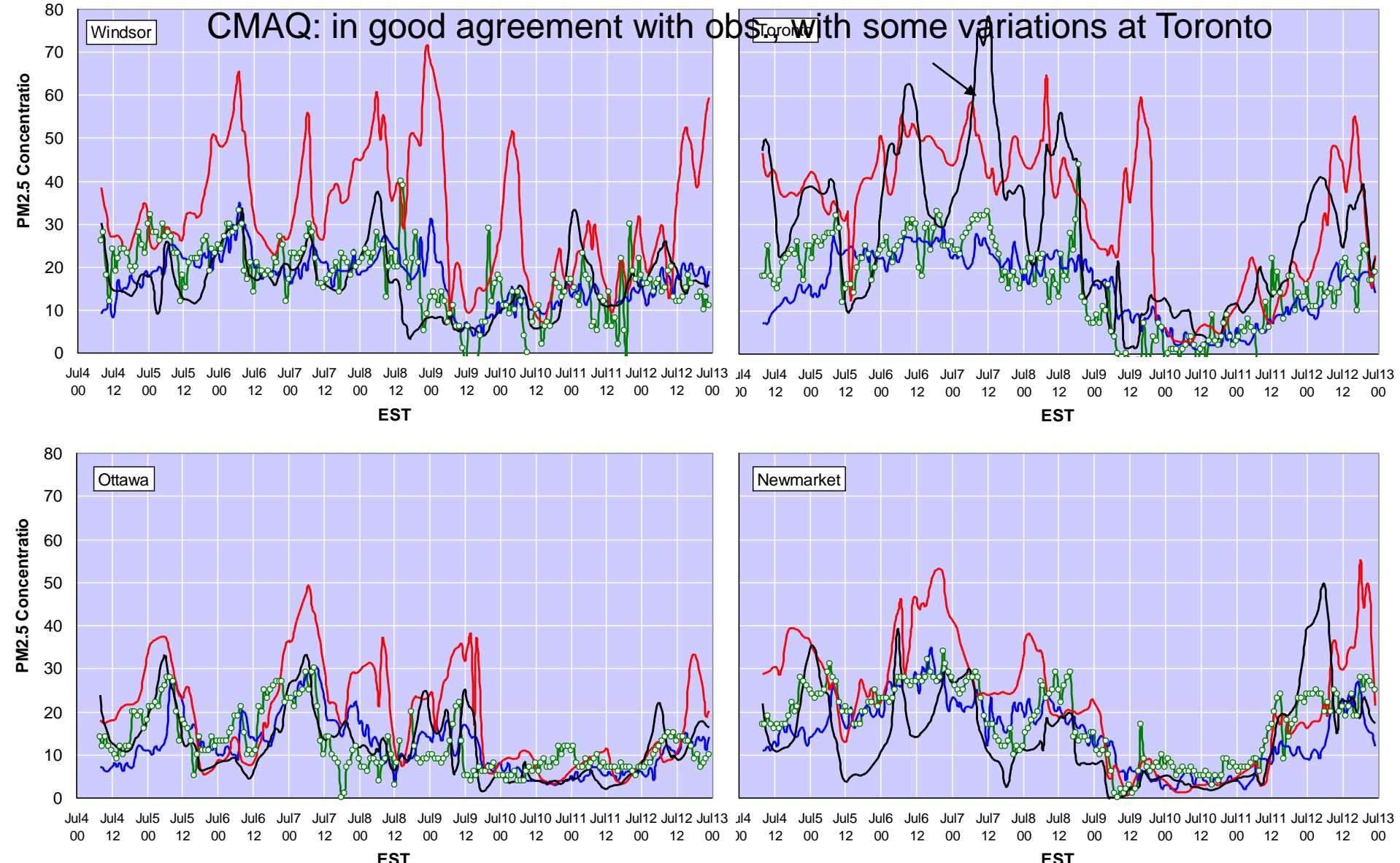
CMAQ: 2010030912 Surface PM_{2.5} Valid at 20100309 13:00UTC



Case Study#1: March 09, 2010, 1600 UTC



Case Study#2: July 4-9, 2010 Heat Wave



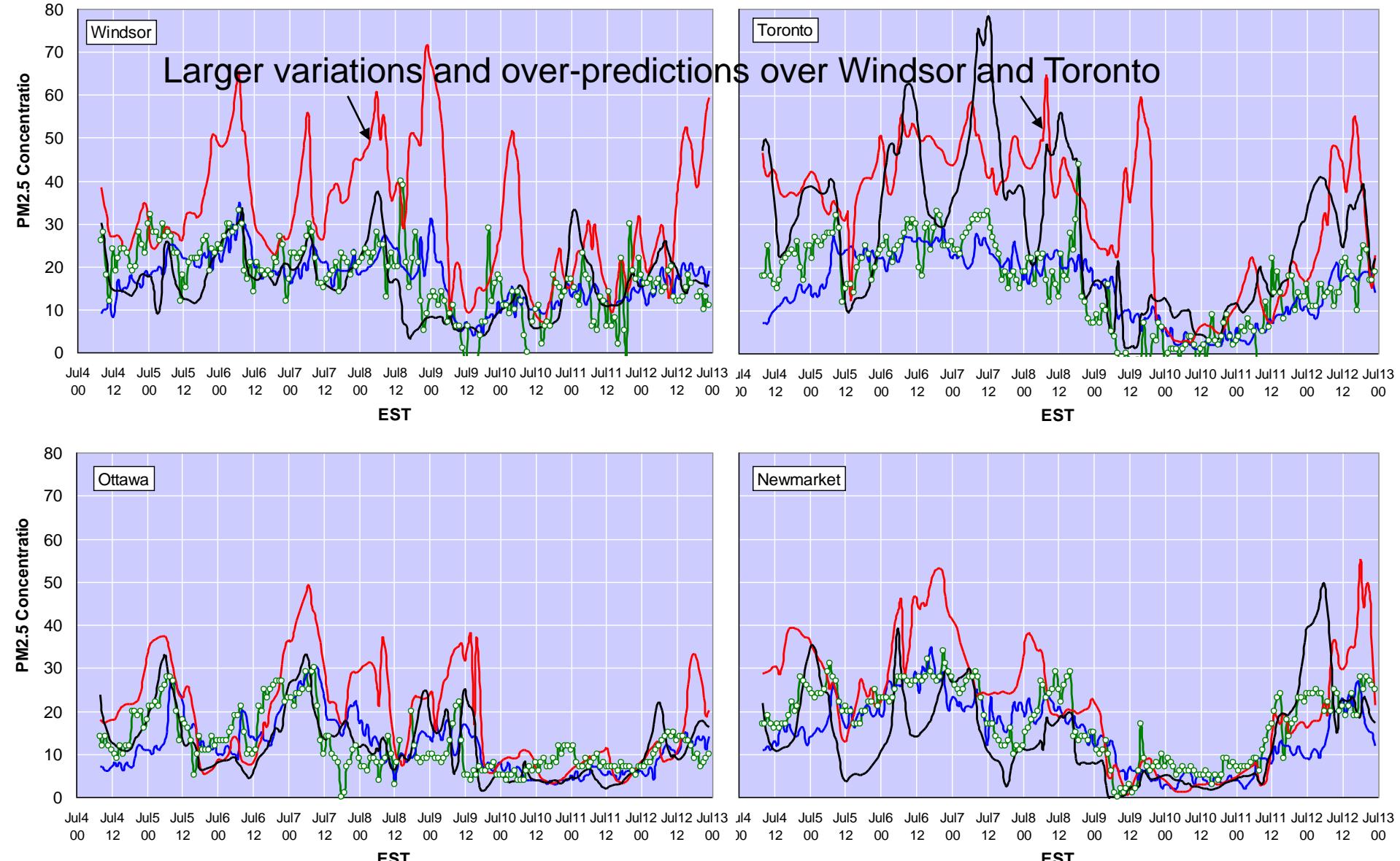
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OBS MACH CMAQ UMOS-AQ



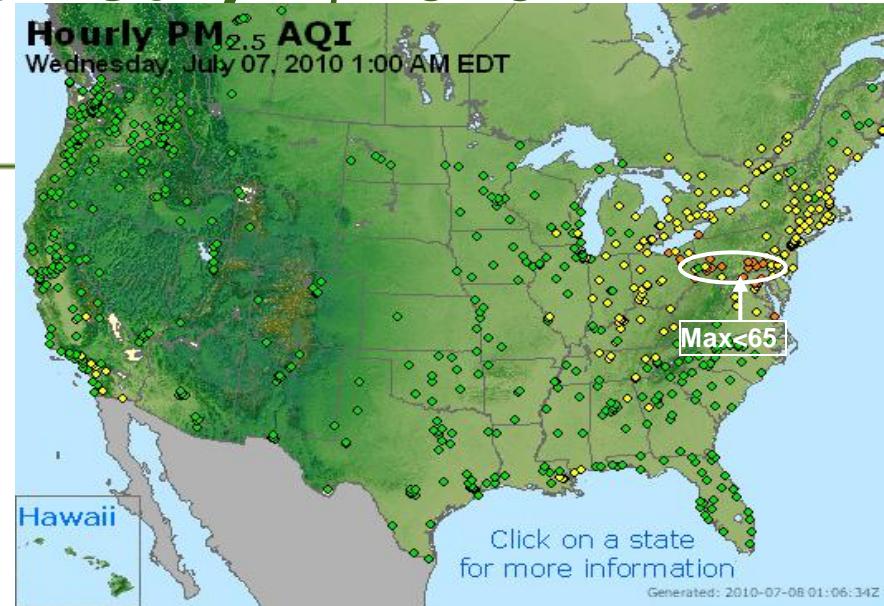
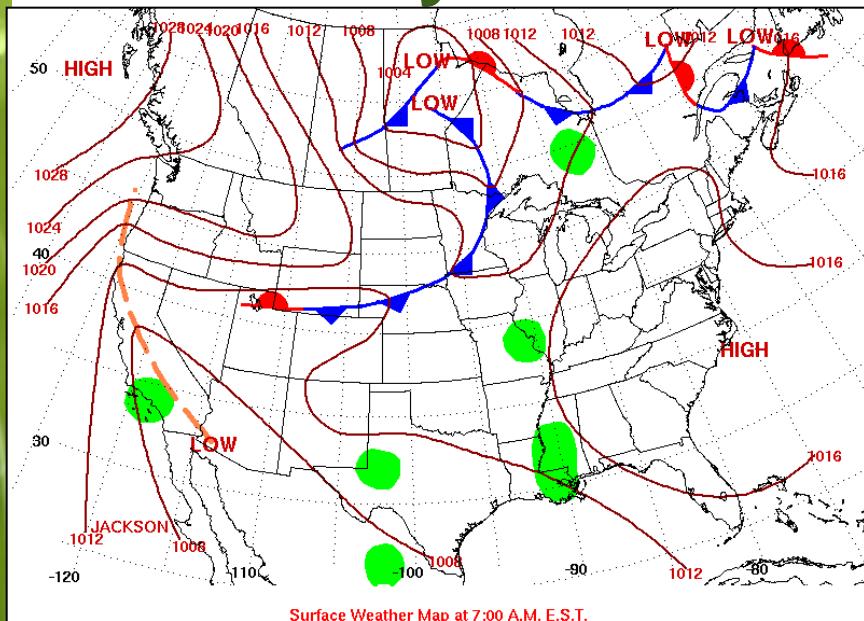
Case Study#2: July 4-9, 2010 Heat Wave



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Case Study#2: Focus on July 7, 2010



Synoptic situation contributing to poor air quality:

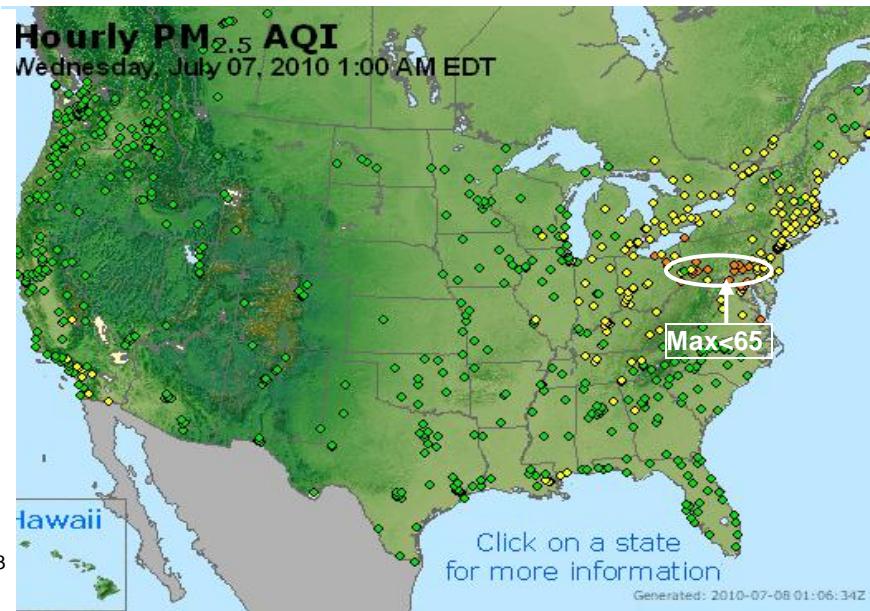
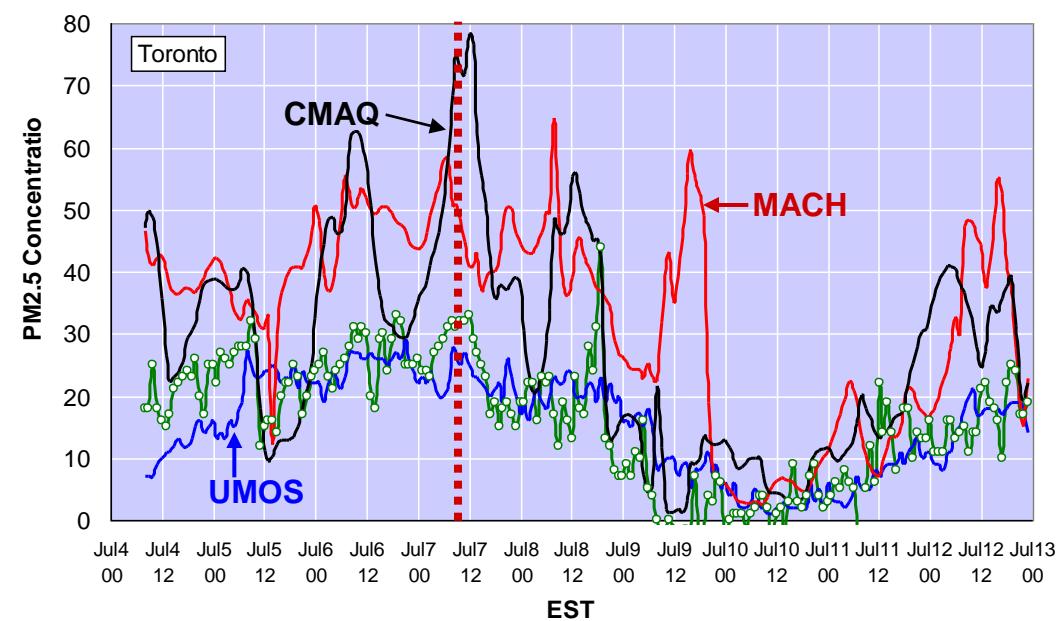
- Strong upper level ridge of high pressure
- Corresponding surface high centered over the western Mid-Atlantic region
- Clear skies, high temperature, light/calm winds, limited vertical mixing, rising dew points, and a modifying airmass composed of a classic recipe



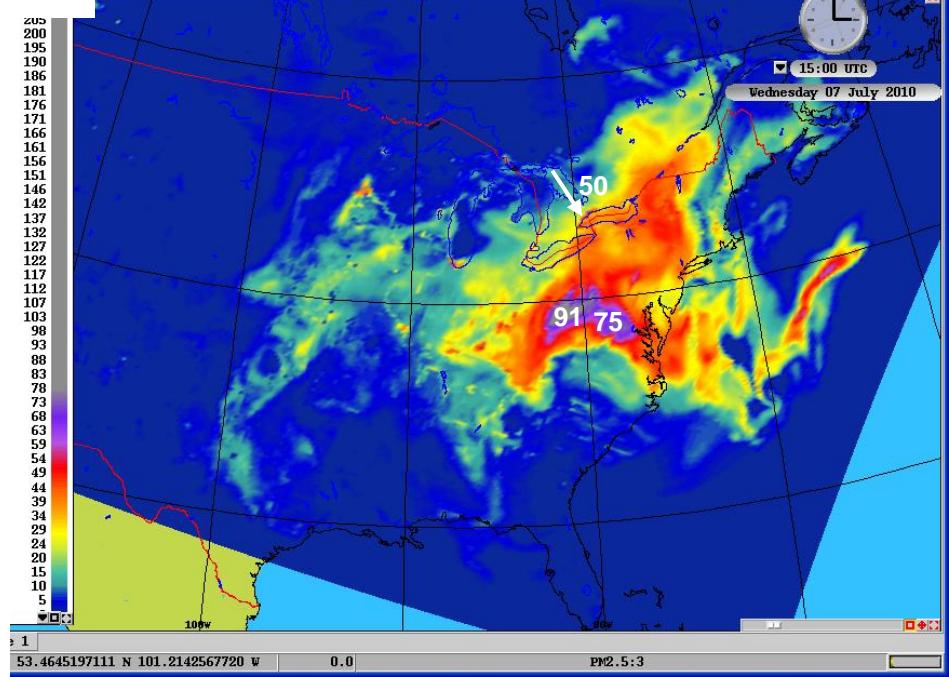
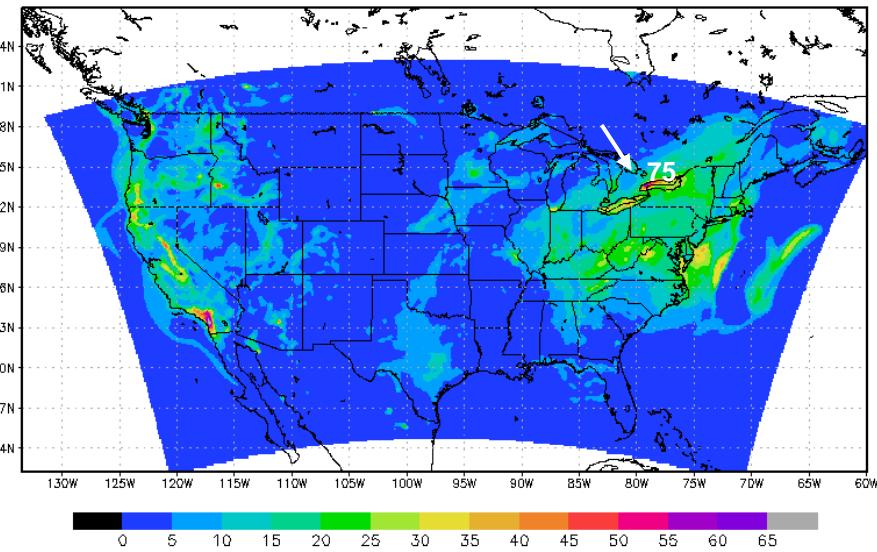
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Case Study#2: July 7, 2010, 1500 UTC



CMAQ: 2010070712 Surface PM_{2.5} Valid at 20100707 15:00UTC



Evaluation Summary (1)

For this period and over 14 (urban) sites in Ontario:

- Both CMAQ and GEM-MACH15 over-predicted PM_{2.5} at the urban centres year-round;
- GEM-MACH15 performs better than CMAQ during cold months, whereas CMAQ shows high bias across the regions, in particularly over the GTA area;
- During the warm (summer) months, CMAQ is in a better agreement with the measurements across the study sites, with significantly reduced bias and model error;
- The Updatable MOS tool (UMOS-AQ) showed encouraging results with significant improvement over the model's direct guidance, and proved to be a very useful tool for the forecasters (but limited to urban cities/sites).

Evaluation Summary (2)

- Uncertainty in emissions inventory and emissions processing for Canada, in particular, emissions sources in big urban cities such as Toronto and its surrounding area, is likely a major contributor to the over-prediction of CMAQ total PM2.5;
- Segregated study for GEM-MACH15 PM2.5 forecasts for urban and rural sites suggests that primary PM2.5 emissions may be one of the causes for producing biased high predictions; For future evaluation work, similar analysis would be done with CMAQ PM forecast;
- Given the complexity of the model structures and the various inter-related physical and chemical processes, it is challenging to evaluate the contributions of individual science processes and PM species to the differences in model performance.

Merci – Thank you

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